International Congress of Imaging Science 2002, Tokyo

Electrical Twisting Sticks in a Transparent Tube

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Abstract

There has been increasing interest in electronic paper that combines the advantages of paper with the re-writable characteristics of a conventional display. An electrical twisting ball display called "Gyricon" is one of the most promising candidates for electronic paper. In this present work, we disclose a novel idea, named "Peas in a pod", which is a potential improvement on "Gyricon". "Peas in a pod" uses the same principle as "Gyricon" in that the display elements react to an electric charge and then make recognizable patterns. However, in the case of "Peas in a pod", microsticks in a transparent tube are used as display elements instead of the microspheres used in "Gyricon". We call the microsticks "Peas" and the transparent tube the "Pod", respectively. A theoretical study suggests that the microsticks in "Peas in a pod" have a potential advantage over the microspheres in "Gyricon" as display elements with respect to response time. This is because the total driving moment of a microstick is found to be larger than that of a microsphere. A model experiment supported the theoretical study above, and the response time of the microstick is indeed quicker than that of the microsphere.

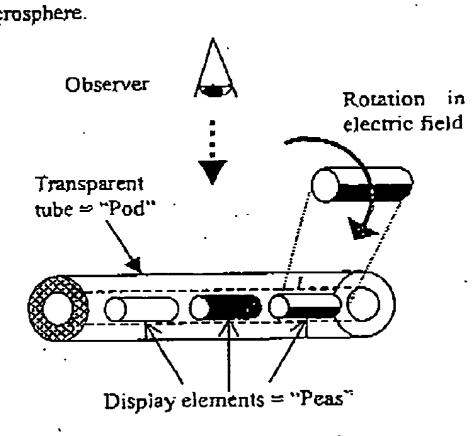

Fig. 1 A schematic diagram showing "Peas in a Pod".

Introduction

The advantages of paper are that it is easy to read, thin, lightweight, stable, flexible, handy and low cost. The only problem with paper is that the information printed on it is unchangeable, in other words, it can't be updated. One answer to this problem is a hybrid which combines the advantages of paper with the chameleon nature of a conventional liquid crystal display. Suppose you could instantly erase the contents printed on paper at anytime, then input something new. This is what we will call electronic paper in this work.

Over the years, several groups have looked at various candidates for electronic paper including reflective liquid crystal systems, "Gyricon"[1)] and "E-ink"[2)]. The latter two candidates, which are particle types, seem to be preferable because they have properties which are close to those of conventional paper, such as their readability, bistability and low cost. Therefore, in our research program, we have focused on these particle types.

The mechanism of "Gyricon", which we believe to be one of the most promising candidates for electronic paper, is as follows: Thousands of tiny microspheres are suspended in a liquid which is encased within a thin sheet. Each microsphere has two colors: one hemisphere is black, the other white. The hemispheres have different electric charges. Two electrodes are applied to the front and back of the sheet. The electric charge on the electrodes determines which side of each microsphere rotates upward. For example, a positive charge will cause the white side to rotate upward. Then the patterns of black and white can create letters and words.

We have pushed the idea of "Gyricon" in new directions. In our research, microsticks in a transparent tube are used as display elements instead of the microspheres in "Gyricon". We call the microsticks "Peas" and the transparent tube the "Pod". "Peas in a pod" uses the same principle as "Gyricon". "Peas" react to an electric charge and then make recognizable patterns. We believe "Peas in a pod" has potential advantages over "Gyricon" with respect to response time. Therefore, in this present work, we describe "Peas in a Pod", with particular emphasis on response time.

Theory

Over the last 20 years, microspheres have been investigated as display elements in "Gyricon", so it might seem as if the shape of the display elements must be spherical. Our question here is: Why must they always be spheres? For example, why not sticks? Therefore, in our research program, we have started to investigate the difference in the dynamics between spheres and sticks.

The rotation of both spheres and sticks can be observed in the same way from their cross-sections as shown in Figure 2. A coulomb force is created when electric field, E, is applied, because the sphere or stick has an electric charge, σ. When the boundary between the black and white regions is θ degrees off the perpendicular to the electric field, a driving moment, large M, is created and the sphere or stick starts to rotate. The rotation creates a dragging moment, small m, because the liquid around the element has viscosity, μ.

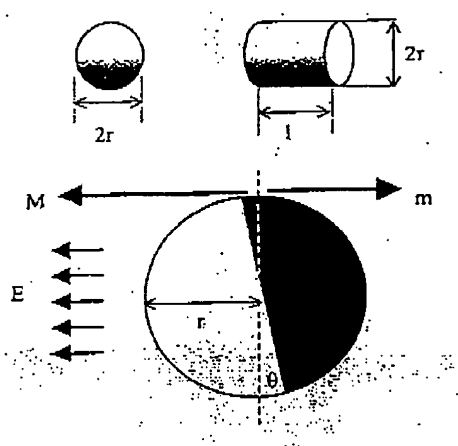

Fig. 2 Cross-sectional view of a sphere/stick.

The equations comparing the moments are summarized in Table 1. The difference in moments between spheres and sticks results from their volumes and surface areas, although we will not deal with the derivation of these equations here. In order to compare the total moment of sphere and stick, we used M/m instead of M-m. This is because the length of the stick, l, disappears during the calculation process. The result suggests that M/m of a stick is 1.5 times larger than that of a sphere, independent of the length l. Therefore, we conclude that a stick has a potential advantage over a sphere as a display element from a dynamic point of view.

Table 1 Composition of moment

	Sphere	Stick
Driving M	$(8/3)\sigma r^3 E\sin\theta$	$2\sigma r^2 l E\sin\theta$
Dragging m	$8\pi\mu r^3\omega$	$4\pi\mu r^2 l\omega$
M/m	(1/3)X	(1/2)X

* $X = \sigma E\sin\theta/\pi\mu\omega$

Experiment

A model experiment was carried out in order to demonstrate the hypothesis based on the theoretical study above. In Figure 3, a sphere or stick made of nylon whose surface is divided into two areas with different colors, is placed between two electrodes and floated at the boundary between two dielectric liquids with different specific gravities (Isoper-G:0.75 and PF-5052:1.70). D.C. voltage is set between the pair of electrodes and the rotation of the sphere or stick is recorded using a video camera (SONY DCR-TRV10).

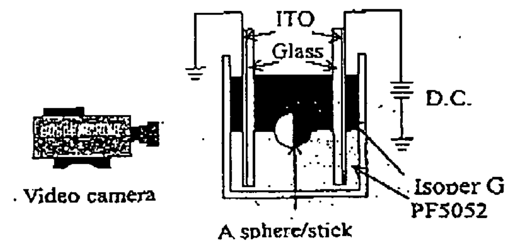

Fig. 3 Experimental apparatus (Side view).

Results and discussion

We observed the motions of the sphere and the stick in ultra slow mode because they were too quick to catch them in natural mode. In the case of the stick, only 1 frame is used to record its half rotation, while with the sphere, 2 frames are required. Considering that the video tape records 30 frames per second, the response time for the half rotation of the stick is calculated to be at most 33 ms, while that of the sphere is in the range 33-66 ms.

Therefore, there is no doubt that the stick has an advantage over the sphere as the display element in terms of the response time. We believe that the quicker response time of the stick results from its larger driving moment.

Conclusion

We have introduced "Peas in a pod", which is a potential improvement on "Gyricon". "Peas in a pod" uses microsticks as display elements instead of the microspheres in "Gyricon".

A theoretical study suggests that sticks have a potential advantage over spheres as display elements. This is because the total driving moment of a stick is found to be larger than that of a sphere. A model experiment supported the hypothesis, and the response time of the stick is indeed quicker than that of the sphere.

References

1. N. K. Sheridon and M. A. Berkovitz, *Proceedings of the S.I.D.*, 18/3&4, 289 (1977).
2. B. Comiskey et al., *Nature*. 394/16, 253 (1998).